LACK OF BILATERAL GENERALIZATION OF ADAPTATION TO AUDITORY REARRANGEMENT

by

Harutune H. Mikaelian
with
Joseph S. Russotti

NAVAL SUBMARINE MEDICAL RESEARCH LABORATORY
REPORT NUMBER 715

Bureau of Medicine and Surgery, Navy Department
Research Work Unit MF51.524.004-9010DA5G.20

Transmitted by:

J. Donald Harris

J. Donald Harris, Ph.D.
Head, Auditory Research Branch

Reviewed and Approved:

Charles F. Gell

Charles F. Gell, M.D., D.Sc.(Med)
Scientific Director
NavSubMedRschLab

Approved and Released by:

J. H. Baker

J. H. Baker, CAPT MC USN
Officer in Charge
NavSubMedRschLab

SUMMARY PAGE

THE PROBLEM

Theoretical speculations concerning the presence or absence of intermanual transfer under differing conditions of sensorimotor adaptation have assumed that the adaptation produced by them are essentially equivalent. The possibility remains that sensorimotor changes generated by these different exposure conditions may be dissimilar. In order to resolve this, it is necessary to obtain relevant information from exposure conditions that provide adequate controls. Auditory rearrangement produced by functional rotation of the interaural axis by pseudophones (a binaural microphone/earphone array worn on the head), represents an exposure condition with suitable controls. Intermanual transfer of adaptation to rearranged ear-hand coordination produced after exposure to a 30° shift of the interaural axis was therefore investigated.

FINDINGS

Except for one exposure condition, changes in ear-hand coordination that occur to compensate the distortion induced by the pseudophones, fail to transfer intermanually. Such results suggest a differential representation of the sensorimotor function between the hemispheres.

APPLICATION

These findings are useful in design of auditory passive detection systems employing auditory tracking. They are for use of systems designers and human factors applications where sensorimotor tasks under conditions of perceptual rearrangement are anticipated. This information is of definite value to Naval medical officers in ear, nose, and throat specialities, and to audiologists.

ADMINISTRATIVE INFORMATION

This investigation was conducted as part of Bureau of Medicine and Surgery Research Work Unit MF51.524.004-9010DA5G. The present report is No. 20 on this Work Unit. It was approved for publication on 20 June 1972 and designated as NSMRL Report No. 715.

This research was supported in part by O.N.R. Contract No. N00014-67-C-0466. The experiments were conducted at the Auditory Research Branch of the Submarine Medical Research Laboratory at the U.S. Naval Submarine Base, New London, Groton, Connecticut.

PUBLISHED BY THE NAVAL SUBMARINE MEDICAL RESEARCH LABORATORY

ABSTRACT

Intermanual transfer of adaptation to rearranged ear-hand coordination produced after exposure to a 30° shift of the interaural axis was investigated by use of electronic pseudophones (a binaural microphone/earphone array worn on the head). Results showed that except for one exposure condition, changes in ear-hand coordination that occur to compensate the distortion induced by the pseudophones fail to transfer intermanually. Such results suggest a differential representation of the sensorimotor function between the hemispheres.

LACK OF BILATERAL GENERALIZATION OF ADAPTATION TO AUDITORY REARRANGEMENT

INTRODUCTION

In 1962, Mikaelian[9] reported that shifts in eye-hand coordination, produced by viewing the arm through wedge prisms, fail to transfer intermanually. Other studies since have shown that it is possible to obtain intermanual transfer of adaptation following certain conditions of prism viewing. Hamilton[4] and Harris[5], among others, have reported that when, during prism viewing, S is allowed to move his head and/or body while moving his arm, the ensuing adaptation transfers intermanually. Kalil and Freedman[8], Cohen[1], Goldberg, Taub, and Berman[3], and others, have reported similar results following exposure that consisted of S reaching for a target with his arm, while viewing both his reaching arm and the target through prisms.

Theoretical speculations concerning the presence or absence of intermanual transfer in prism adaptation, as reported in these studies, have emphasized the conditions which produce or inhibit intermanual transfer, with the assumption that adaptation produced by them are essentially equivalent. The possibility that the sensorimotor changes generated by these different exposure conditions may be dissimilar emerges from an analysis of these conditions. For example, moving the head or body during prism vision, a condition reported to be instrumental for intermanual transfer, generates visuo-motor changes that appear as alterations in the orientation of the body to external visual targets (ego-centric localization) (Hamilton[4], Held and Hein[7]). Thus, subsequent orientation of any limb to a visual target, regardless of the laterality of the limb, will manifest corresponding changes. Clearly, such a phenomenon is better described as generalization rather than transfer of adaptation from one arm to the other. The relationship between the geometry of movement and the patterns of sensorimotor adaptation that bears on this matter has been discussed elsewhere (Mikaelian[10]).

Intermanual transfer of response alterations produced by prism viewing of the arm reaching for targets should also be interpreted cautiously. A subject, detecting errors induced by prism vision while reaching for a target, can readily and fully correct them, usually within a few trials, by simply shifting his motor response. Such a correction is more akin to a simple motor skill readily available to either limb. In those experiments conducted by Mikaelian, S viewed his arm on a homogeneous background, often unable to resolve the nature of the prism transform. Adaptation was gradual and after 10 minutes reached only about 60%.

The usefulness of theoretical stipulations of adaptation processes, formulated on the basis of intermanual transfer data from experiments where adaptation could be contaminated by the factors discussed above, is limited.

It is necessary to obtain relevant information from exposure conditions that provide adequate controls for these variables.

Auditory rearrangement, produced by functional rotation of the interaural axis by pseudophones, represents an exposure condition with suitable controls. Typically, adaptation is produced by having a blindfolded S move a hand held sound-source while listening through pseudophones. The direction and magnitude of the differences between pre- and post-pseudophone exposure measurements of ear-hand coordination are systematically related to the functional rotation of the interaural axis. (Freedman et al.[2], Mikaelian[11].) Unlike viewing through prisms, S listening through pseudophones cannot resolve the imposed sensory transform. Furthermore, the absence of external targets to be reached during exposure as well as the lack of external frames of reference make it difficult for him to judge the accuracy of his movements and thus correct for "error." Head movements, of course, are easily controllable. Auditory rearrangement, then, provides a "clean" condition in which to test for intermanual transfer of sensorimotor adaptation. The following experiment was accordingly designed.

METHOD

Apparatus. The experiments were conducted in an anechoic chamber (for frequencies above 100 Hz). The testing apparatus (Fig. 1) consisted essentially of a masonite board 24 in. by 188 in. curved to a radius of 30 in. The semicircular board was supported by Dexion frames with its base 32 in. from the floor and its vertical surface in S's frontal parallel plane. The board served to support the targets and the paper on which S marked their location. The targets consisted of earphones (permaflux PDR-8) mounted on wooden supports (light targets were also mounted on the wooden board but were not used in this experiment). Subject's head rested on a chin rest at the geometric centre of the curved testing apparatus.

The pseudophones consisted of a pair of Altec 21 condenser microphones fitted with plastic cast artificial pinnae (supplied by the Laboratory for Research in Neuropsychology in Boston). The microphones, with the pinnae, were mounted 7-1/2 in. apart on a lucite bar which was attached to a pair of headphones such that the bar rested on S's head and could be rotated. The output from each microphone was amplified separately (WEAL Type 100 D/E) and fed into its corresponding right or left headphone (PDR-8). Rotation of the pseudophone axis produced a lateral shift of the auditory field towards the leading ear.

Wide band pulsed noise 65 dB SPL (re .002 dynes/cm^2) with a 30 msec. on and 60 msec. off sequence was used as the signal to be localized during testing. The experimenter could direct the test signals into any one of the three targets through a set of push-button switches.

Procedure. Training, testing, and exposure procedures used in this experiment were identical to those reported in an earlier paper (Mikaelian[11]). Training

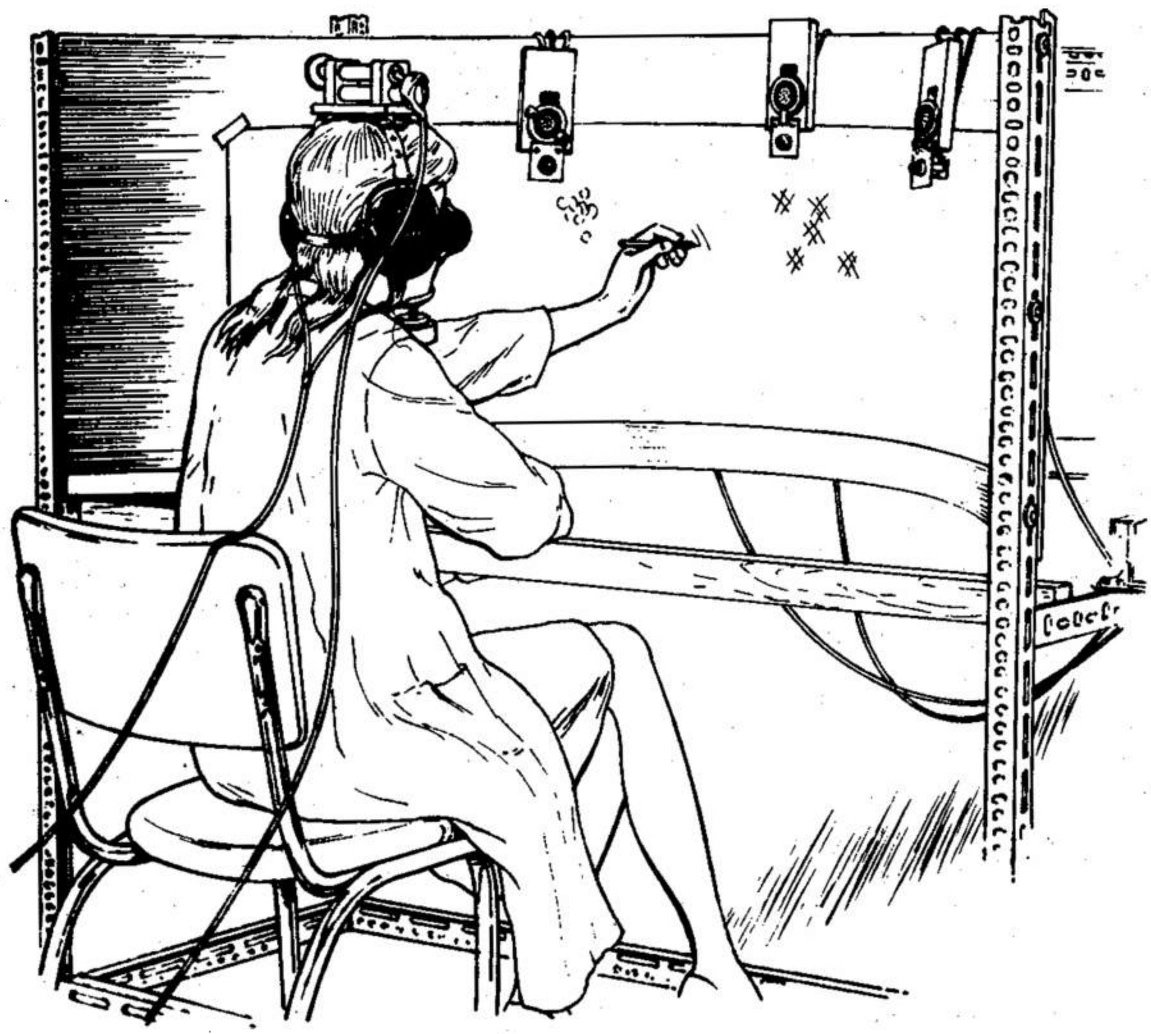

Fig. 1. Ear-Hand Coordination Test Apparatus

consisted of practice in locating the position of a sound target, while listening through pseudophones, until a criterion of accuracy was reached. Testing consisted of marking the position of the sound targets on the test apparatus with pseudophones in normal orientation (axis of pseudophones parallel to the interaural axis). Exposure entailed moving a hand-held sound source that emitted a train of pulses, possessing the same parameters as the test signal, in a semicircular path around the head while listening through pseudophones.

Subject wore opaque goggles during the entire proceedings. The sequence for each experimental session was as follows: with the pseudophones in normal orientation, S marked the position of the three auditory targets five times in a random order, first using one arm and then the other. Following pre-exposure testing, the pseudophones were rotated by 30°, S was handed the sound source and instructed to move it. At the end of 20 min. of exposure, pseudophone orientation was returned to normal and post-exposure markings taken, first using the contralateral (unexposed) arm and then the ipsilateral (exposed). Intermanual transfer was measured by the difference between pre- and post-exposure tests with the exposed and unexposed arm. Sixteen right handed Ss with no apparent hearing defects were used. They were assigned randomly to two groups: Group I, exposed to rearrangement with the right ear leading; and Group II, exposed to rearrangement with the left ear leading. Each S was tested in two sessions separated by at least 24 hrs. In one session the right arm was used for exposure and in the other the left. The order of arms used for exposure was counterbalanced in each group.

RESULTS AND DISCUSSION

The results are shown in Tables I and II. Each number represents, in degrees of angular displacement, the mean difference between pre- and post-exposure markings of the positions of the three auditory targets. The measurements, being taken with the pseudophones in normal orientation, represent aftereffect errors in localizations. Positive differences represent ear-hand coordination changes in the expected (adaptive) direction; that is, in a direction opposite to the pseudophonic displacement. Negative values represent unadaptive changes.

The data show that the changes in ear-hand coordination entailing the exposed, or ipsilateral, arm are statistically reliable ($p < 0.01$, t-test for correlated means), those entailing the unexposed, or contralateral, arm are, except for the Left Ear Leading - Left Arm exposure condition (Table II), not reliably different from zero. Although the data reflect a good deal of individual differences in magnitude of adaptation, a common observation in adaptation studies, the responses of most subjects are quite consistent. Systematic changes in ear-hand coordination follow exposure to auditory rearrangement, confirming earlier reports (Freedman et al.[2]: Mikaelian[11]); however, these changes occur mostly in responses with the ipsilateral arm and, except for one condition, fail to transfer intermanually.

These observations reflect an interesting asymmetry. Three of the four conditions indicate failure of intermanual transfer of adaptation to auditory rearrangement while the fourth reflects transfer. Failure of adaptation to transfer intermanually signifies that when the sensory flux during exposure to distorted feedback arises from arm movements, the consequent sensorimotor changes are confined mostly to responses made with that arm. This rule, which has also been shown to hold

Table I. Transfer of Adaptation to Rearranged Ear-Hand Coordination Right Ear Leading (in degrees of angular displacement)

Exposed Arm	Left Arm		Right Arm	
Tested Arm	LA	RA	LA	RA
Subjects				
1	5.0°	-3.0°	2.3°	3.0°
2	1.5°	-0.5°	-3.0°	8.5°
3	4.0°	1.0°	0.0°	2.3°
4	9.0°	-2.4°	-5.4°	5.4°
5	14.4°	0.3°	-0.3°	0.9°
6	10.5°	-0.9°	0.0°	11.4°
7	11.1°	0.9°	0.0°	11.4°
8	7.5°	1.5°	3.6°	9.0°
$\overline{X}$	7.9°	-0.4°	-0.4°	6.5°
p(t-test)	0.01	N.S.	N.S.	0.01

for vision, appears to be a relatively stable feature of sensorimotor adaptation, and must be incorporated in any theory of its underlying processes.

The presence of intermanual transfer in one of the conditions is a puzzling finding. Following 20 min. of pseudophonic listening with the left ear leading, and the left arm moving the sound source, significant changes in ear-hand responses made with both the ipsilateral and the contralateral arm occur ($p > 0.02$, t-test for correlated means). Evidently adaptation produced by this exposure condition generalizes, while that produced by the other conditions are confined to the exposed arm. None of the theories in the literature make provisions for such an asymmetry, although asymmetries in adaptation have been reported by others (Held[6]). Explanation of asymmetries must be obtained from further experimentation,

Table II. Transfer of Adaptation to Rearranged Ear-Hand Coordination
Left Ear Leading (in degrees of angular displacement)

Exposed Arm	Left Arm		Right Arm	
Tested Arm	LA	RA	LA	RA
Subjects				
9	7.8°	12.0°	1.5°	11.4°
10	16.8°	-0.9°	2.4°	10.5°
11	11.4°	-0.6°	-6.9°	4.8°
12	3.9°	6.0°	0.0°	13.8°
13	11.0°	11.0°	0.0°	3.8°
14	12.5°	6.0°	0.8°	4.8°
15	5.7°	8.5°	10.7°	8.0°
16	3.0°	2.0°	-1.8°	1.2°
$\bar{X}$	9.0°	5.5°	0.8°	7.3°
p(t-test)	0.01	0.02	N.S.	0.01

however, the data from the Left Ear Leading - Left Arm condition of the present experiment lend themselves to an interesting analysis in terms of hemispheric dominance. The auditory information about the moving sound source (mediated primarily by the left ear) and the motor information about this movement (left arm) were processed during exposure by the right cerebral hemisphere; this being the only condition where the relevant sensorimotor information was processed mainly by that hemisphere. A differential representation of the sensorimotor function between the hemispheres (the left being focal and the right diffuse in representation for right hand dominance) has been suggested by Semmes[12]. Our Ss were all right handed, and it could be that the asymmetry of intermanual transfer reflects the asymmetry in hemispheric functioning. Such an approach opens new lines of investigations that may prove fruitful.

SUMMARY

Intermanual transfer of adaptation to rearranged ear-hand coordination, generated by exposure to a 30° rotational shift of the interaural axis was explored. The results collected on 16 Ss showed that, except for one exposure condition, changes in ear-hand coordination that compensate the distortion induced by 30° aural shift fail to transfer intermanually. These findings are similar to observations on visual adaptation.

REFERENCES

1. Cohen, M. Continuous vs terminal feedback in prism after-effects. Percept. Mot. Skills, 1967, 24, 1295-1302.

2. Freedman, S. J., Wilson, L., & Rekosh, J. H. Compensation for auditory rearrangement in ear-hand coordination. Percept. Mot. Skills, 1967, 24, 1707-1710.

3. Goldberg, I. A., Taub, E., & Berman, A. J. Decay of prism aftereffect and interlimb transfer of adaptation. Paper presented at the meeting of the Eastern Psychological Association, Boston, 1967.

4. Hamilton, C. R. Studies on adaptation to deflection of the visual field in split-brain monkeys and man. (Doctoral dissertation, Cal. Inst. of Tech.) Ann Arbor, Mich: University Microfilms, 1964, No. 64-11, 398.

5. Harris, C. S. Adaptation to displaced vision: A proprioceptive change. (Doctoral dissertation, Harvard University) Ann Arbor, Mich.: University Microfilms, 1963, No. 63-8162.

6. Held, R. Shifts in binaural localization after prolonged exposures to atypical combinations of stimuli. Amer. J. Psych., 1955, 68, 526-548.

7. Held, R. and Hein, A. Transfer between visual-motor systems of adaptation to prismatic displacement of vision. Paper presented at the meeting of the Eastern Psychological Association, New York, 1960.

8. Kalil, R. E. and Freedman, S. J. Intermanual transfer of compensation for displaced vision. Percept. Mot. Skills, 1966, 22, 123-126.

9. Mikaelian, H. H. Failure of intermanual transfer of adaptation to rearranged eye-hand coordination. Paper presented at the meeting of the Eastern Psychological Association, Philadelphia, 1962.

10. Mikaelian, H. H. Relation between adaptation to rearrangement and the source of motor sensory feedback. Psychonomic Science, 1967, 9, 485-486.

11. Mikaelian, H. H. Adaptation to rearranged ear-hand coordination, Percept. Mot. Skills, 1969, 28, 147-150.

12. Semmes, J. Hemispheric specialization: A possible clue to mechanism. Neuropsychologia, 1968, 6, 11-26.

UNCLASSIFIED
Security Classification

DOCUMENT CONTROL DATA - R & D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1. ORIGINATING ACTIVITY (Corporate author) NAVAL SUBMARINE MEDICAL CENTER NAVAL SUBMARINE MEDICAL RESEARCH LABORATORY	2a. REPORT SECURITY CLASSIFICATION UNCLASSIFIED 2b. GROUP

3. REPORT TITLE

LACK OF BILATERAL GENERALIZATION OF ADAPTATION TO AUDITORY REARRANGEMENT

4. DESCRIPTIVE NOTES (Type of report and inclusive dates)
Interim report

5. AUTHOR(S) (First name, middle initial, last name)
Harutune H. Mikaelian
with Joseph S. Russotti

6. REPORT DATE	7a. TOTAL NO. OF PAGES	7b. NO. OF REFS
20 June 1972	8	12

8a. CONTRACT OR GRANT NO. O.N.R. Contract No. N00014-67-C-0466 b. PROJECT NO. MF51.524.004-9010DA5G c. d.	9a. ORIGINATOR'S REPORT NUMBER(S) NSMRL Report No. 715 9b. OTHER REPORT NO(S) (Any other numbers that may be assigned this report)

10. DISTRIBUTION STATEMENT

Approved for public release; distribution unlimited.

11. SUPPLEMENTARY NOTES	12. SPONSORING MILITARY ACTIVITY
	Naval Submarine Medical Center Box 600 Naval Submarine Base Groton, Connecticut 06340

13. ABSTRACT

Intermanual transfer of adaptation to rearranged ear-hand coordination produced after exposure to a 30° shift of the interaural axis was investigated by use of electronic pseudophones (a binaural microphone/earphone array worn on the head). Results showed that except for one exposure condition, changes in ear-hand coordination that occur to compensate the distortion induced by the pseudophones fail to transfer intermanually. Such results suggest a differential representation of the sensorimotor function between the hemispheres.

DD FORM 1 NOV 65 1473 (PAGE 1)
S/N 0102-014-6600

UNCLASSIFIED
Security Classification

14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Sensorimotor Adaptation						
Auditory Adaptation						
Auditory Localization						
Auditory Rearrangement						
Perceptual Rearrangement						
Intermanual Transfer						
Pseudophones						
Proprioception						
Adaptation to Displaced Hearing						